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In re Patent Application of:
OLSSON ET AL.
Serial No. **09/147,230**
Filed: **FEBRUARY 9, 1999**

Listing of Claims:

This listing of claims replaces all prior versions and listing of claims in the application.

Claims 1-29 (previously cancelled).

30. (previously added) A receiver, for use in an OFDM transmission system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, the receiver comprising:

a sampling oscillator; and

control means for controlling said sampling oscillator and comprising estimation means for estimating timing deviations of said sampling oscillator;

said estimation means operating entirely on frequency domain input data.

31. (previously added) A receiver, for use in an OFDM transmission system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, the receiver comprising:

a sampling oscillator;

an adaptive equalizer having an equalizer inverse channel model;

separation means for separating the equalizer inverse channel model into a first and a second part, the first part being independent of sample timing and the second part being dependent on sample timing; and

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control means for controlling the sampling oscillator based upon the second part.

32. (previously added) A receiver according to Claim 31 wherein said control means comprises estimation means for estimating timing deviations of said sampling oscillator; and wherein said estimation means operates entirely on frequency domain input data.

33. (previously added) A receiver according to Claim 32 wherein said estimation means estimate an approximation of a linear portion of an argument function produced by timing deviations of said sampling oscillator.

34. (previously added) A receiver according to Claim 32 wherein said estimation means finds the linear portion of the argument function by taking an average slope of the argument function.

35. (previously added) A receiver according to Claim 34 wherein the approximation of the linear portion of the argument function is used as a feedback control signal for said sampling oscillator.

36. (previously added) A receiver according to Claim 35 further comprising a control loop for said sampling oscillator; and wherein the approximation of the linear portion of the argument function has a slope which converges to zero as the control loop settles.

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37. (previously added) A receiver according to Claim 36 wherein parts of the equalizer inverse channel model, other than the linear portion of the argument function, are controlled by said adaptive equalizer which continuously adapts to variations in sampling timing.

38. (previously added) A receiver according to Claim 37 wherein said adaptive equalizer and said control means each use defined and different portions of the equalizer inverse channel model to achieve an output frequency domain signal with zero phase deviation relative to a transmitted signal.

39. (previously amended) A receiver according to Claim 36 wherein the slope of the argument function α_k is estimated from an equation

$$\alpha_k = \frac{1}{N}\sum_n L\frac{(X_{n,k})/(Y_{n,k})}{n}$$

where N is the number of active carriers and (Xn,k)/(Yn,k) is the unwrapped argument function for an nth active carrier in a kth frame.

40. (previously amended) A receiver according to Claim 36 wherein the slope of the argument function α_k is estimated from an equation

$$\alpha_k = \frac{2}{n_2 - n_0}\left[\sum_{n=n_1+1}^{n_2} L(X_{n,k})/(Y_{n,k}) - \sum_{n=n_0}^{n_1} L(X_{n,k})/(Y_{n,k})\right]$$

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where N is the number of active carriers, (Xn,k)/(Yn,k) is the unwrapped argument function for an nth active carrier in a kth frame, indices n_0 and n_2 are lower and upper limits respectively of a band and index n_1 which divides the band into two equal parts.

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41. (previously added) A receiver according to Claim 30 wherein on start up, frame timing is adjusted until received frames are sampled within a signal interval.

42. (previously added) A receiver according to Claim 41 further comprising means responsive to a feed back control for said sampling oscillator to adjust the frame timing so that frame synchronization is maintained.

43. (previously added) An OFDM transmission system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, the OFDM transmission system comprising:

a receiver comprising a sampling oscillator and a controller connected thereto;

said controller controlling said sampling oscillator and estimating timing deviations of said sampling oscillator entirely on frequency domain input data.

44. (previously added) An OFDM transmission system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, the OFDM transmission system comprising:

a receiver comprising

a sampling oscillator,

an adaptive equalizer having an equalizer inverse channel model,

a separation circuit for separating the equalizer inverse channel model into a first and a second part, the first part being independent of sample timing and the second part being dependent on sample timing, and

a controller for controlling the sampling oscillator in dependence on the second part.

45. (previously added) In an OFDM system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, a method of synchronizing a receiver sampling oscillator, the method comprising:

controlling the sampling oscillator with a feedback signal representing an estimation of timing deviations of the sampling oscillator, the estimation of timing deviations being derived directly from frequency domain input data.

46. (previously added) In an OFDM system in which data is transmitted in frames, each frame having a cyclic prefix which is a repetition of part of the frame, and in which the receiver comprises an adaptive equalizer having an equalizer inverse channel model, a method of synchronizing a receiver sampling oscillator with a transmitter sampling oscillator, the method comprising:

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separating the equalizer inverse channel model into a first and a second part, the first part being independent of sample timing and the second part being dependent on sample timing; and

controlling a sampling oscillator based upon the second part.

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47. (previously added) A method according to Claim 46 further comprising estimating timing deviations of the receiver sampling oscillator entirely from frequency domain input data.

48. (previously added) A method according to Claim 47 wherein estimating comprises estimating an approximation of a linear portion of an argument function produced by timing deviations of the receiver sampling oscillator.

49. (previously added) A method according to Claim 48 wherein estimating an approximation of a linear portion of an argument function comprises taking an average slope of the argument function.

50. (previously added) A method according to Claim 48 further comprising using the approximation of a linear portion of an argument function as a feedback control signal for the receiver sampling oscillator.

51. (previously added) A method according to Claim 50 wherein the approximation of a linear portion of an argument

function has a slope which converges to zero as a control loop for the receiver sampling oscillator settles.

52. (previously added) A method according to Claim 51 further comprising controlling parts of the equalizer inverse channel model, other than the linear portion of the argument function, with the adaptive equalizer which continuously adapts to variations in sampling timing.

53. (previously added) A method according to Claim 52 wherein the adaptive equalizer and the control loop each use defined and different portions of the equalizer inverse channel model to achieve an output frequency domain signal with zero phase deviation relative to a transmitted signal.

54. (previously amended) A method according to Claim 51 wherein estimating the slope of the argument α_k uses an

$$\alpha_k = \frac{1}{N}\sum_n L\frac{(X_{n,k})/(Y_{n,k})}{n}$$

where N is the number of active carriers, (Xn,k)/(Yn,k) is the unwrapped argument function for an nth active carrier in a kth frame.

55. (previously amended) A method according to Claim 51 wherein estimating the slope of the argument function α_k uses an equation

$$\alpha_k = \frac{2}{n_2 - n_0}\left[\sum_{n=n_1+1}^{n_2} L(X_{n,k})/(Y_{n,k}) - \sum_{n=n_0}^{n_1} L(X_{n,k})/(Y_{n,k})\right]$$

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where N is the number of active carriers, (Xn,k)/(Yn,k) is the unwrapped argument function for an nth active carrier in a kth frame, indices n_0 and n_2 are lower and upper limits respectively of a band and index n_1 which divides the band into two equal parts.

56. (previously added) A method according to Claim 55 further comprising adjusting frame timing, upon starting, until received frames are sampled within a signal interval.

57. (previously added) A method according to Claim 56 wherein adjusting the frame timing comprises adjusting the frame timing in accordance with a feed back signal so that the sampling oscillator maintains frame synchronization.

58. (previously added) An ADSL or VDSL modem comprising:

a receiver in which data is transmitted in frames each frame having a cyclic prefix which is a repetition of part of the frame, the receiver comprising a sampling oscillator and a controller for controlling said sampling oscillator and for estimating timing deviations of said sampling oscillator operating entirely on frequency domain input data.